Eco-Sense
Energy Petal
Prerequisite 04: Net Zero Energy

Preface: It must be noted that before the sustainable/renewable energy systems are discussed, that the per person electrical energy intensity of the occupants of this home is about 90% less than the average person in BC. Reduction of energy consumption both for operations and for amortized construction carbon footprint has been the primary energy strategy.

Electricity (actual)	total/year (kWh)	per person/year
Total Produced from 2kW solar PV array	2469	412
Total Consumed	2154	359
Net surplus	315	53
Electricity - breakdown (estimates)	**total/year (kWh)**	**per person/year**
fans and pumps (heating, ventilation, irrigation, and deep well) 20%	430.8	72
lighting 10%	215.4	36
Domestic plug loads 55%	1184.7	197
Workshop plug loads 15%	323.1	54

Overview of Energy Systems

Eco-Sense has four main energy inputs, two of which are sustainable, one renewable (wood), and the other a fossil fuel. Sustainable Energy systems include the solar PV system and the solar thermal system. The other two (wood and propane) involve inputs that involve a form of combustion. Combustion is not allowed in the pre-requisites of the LBC, but we feel that an explanation of these systems is critical, as we analyzed in depth what the corresponding options would mean with regards to embodied energy, sustainability and the ability to be resilient within the footprint of the project.

One key point of interest is that Eco-Sense is a residence, wherein a large degree of food is prepped and preserved to meet the needs over the period of a year. Most other buildings/residences import food into the building to feed the occupants, wherein the food has been grown, processed, and preserved outside of the building, and thus inhabitants are importing an embodied footprint (both water and energy) from externalized fossil fuel sources. Here, we import only about 20% of food (for Ann, Gord and kids) from the outside. (80% of our food is grown and processed onsite). We have calculated that we would require 12 additional 175w PV panels to cover both families' food prep and preservation needs using resistive cooking, effectively doubling our 2kW solar array to 4kW.

Interconnected systems:

Our energy systems are all interconnected as part of an integrated set of systems. For example our living roof is integral in the performance of our PV generation, as the living roof keeps the panels cooler and thus allows them to work at a lower and more efficient temperature. As a further example of this we utilize a heat dump from the solar thermal tubes to heat a solar dehydrator at the back of the house. Waste summer heat becomes dried food for the winter.

Solar PV:

Eco-Sense has 12 Sharp 175w panels, providing a 2kW array. These panels are wired to feed two parallel Outback MX 60 Charger controllers, an 800 amp hour, sealed AGM battery bank, 3500W Outback Grid-Tie inverter, and linked to the BC Hydro grid. There is no backup power supply. The house is wired primarily for 24VDC, to use the power generated and stored in its purest (least modified) form.

Solar Thermal Hot Water Combination System:

Eco-Sense initiated the first legal solar hot water combination system in BC, supporting document is the Solar Hot Water Alternate Solution document. The system is comprised of 60 Mazdon evacuated tubes (providing a surface area of 6.024 sq metres of collection), plumbed in parallel, with 1" copper tubing, as a closed loop system, filled with a 50% mix of food grade propylene glycol/water. The storage tank is a 120 double coil stainless steel solar boiler; the lower coil is rated at an allowance of 10 gpm feed, though the solar thermal pump, a 12VDC El Sid 20W 12pv circulates the fluid at 3.5 gpm. The lower coil dumps the heat into the tank, allowing heat for both domestic hot water and space heating.

The upper coil in the 120 gallon tank is connected to the closed loop heating system, in-floor hydronics and wood gassification boiler. In the winter heat can be drawn from this heat "take-off" coil to run through the floors, or can circulate in reverse direction when wood boiler is in use to heat the tank. In summer this same coil acts as the heat take-off for the solar thermal heat dump, and dumps excess heat into the wood boiler.

Redesigned Hydronics System

Eco-Sense redesigned the engineered hydronic heating system to be more efficient. The main circulation pump used to circulate fluids through all heating zones, and a recirculation loop was replaced with three small El Sid pumps, wherein each pump controls circulation for each zone. This effectively ensured that power was only used when a zone called for heat, thus eliminating a constant energy draw. Also removed from the engineered hydronics was the electronic zone control valves on the Wirsbro manifolds; with the addition of a check valve on each manifold, and the above mentioned pumps, circulation to zones was controlled in one process thus eliminating phantom loads for the zone control valves. An last additional change was the removal of the electronic digital thermostats in replacement with a conventional mercury free Honeywell 240 AC thermostat; effectively removing the phantom load of the digital system.

Components:
Boiler Circulation Pump - El Sid 12VDC
Boiler Actuator valve - Belimo 24VDC (5W)
Zone Circulator Pumps - 3 X El Sid 12 VDC
Zone Circulator Actuator Valve - Belimo 24 VDC (5W)

All components of the hydronic distribution system are 12 VDC and 24 VDC, thus allowing the generated power of the PV panels to be used in an un altered state, as power that is converted from one form to another experiences efficiency loss in the process.

During a three week cold snap during December 2008, with temperatures from -15 C to -17 C, wherein all pumps ran for approximately 8 hrs in duration, and the actuator valves 12 hrs. The estimated power use to control heat distribution during this extreme event was 760 watts in a 24 hr period.

Overall Energy Inputs and Energy Usage

Solar Thermal Gain and Usage

RETScreen estimate for Victoria for 60 Mazdon Tubes with an aperture area of 60 tubes is 2 x 3.021 sq. m = 6.042 sq. m is: 4.9 MWhr or 4900 kWhrs (annual) based on 484L/127Gal storage. Through Thermomax Industries regional insolation charts and collector efficiency (http://www.solarthermal.com/performance/canada/victoria.html) and the regional solar insolation charts for Victoria BC, based on 70% efficiency = (13 Mj/sq. m X 365) X 6.024 sq.m X 70% = 20008.57 Mj converts to 5.57MWh or 5570 kWhrs.

The Eco-Sense residence has three months wherein most of the solar thermal gain is not used, as the months of June through August only draw energy to meet the demands for their domestic hot water, thus the rest is excess. Based on using the data from the manufacturer, thus erring on the higher energy acquisition, and adjusting for the three months in the summer where only the demand is used, the total solar thermal collection is 4328 kWhrs.

The attached table shows the total available solar thermal gain, and the actualized solar thermal gain.

The research we are currently performing on the home will be able tell us exactly how much of this solar thermal is used for heating and for domestic hot water. See research folder. We will know better when the data from all the different data loggers is fully analyzed and will be writing reports with two consulting engineers involved with the research.

Solar PV Gain and Usage (see chart above)
Solar PV is actual data collected. In the first year of occupation, 2469 kWhrs was generated, and 2154 kWhrs were used, providing a net gain of 315 kWhrs, thus making Eco-Sense a net supplier to BC Hydro. Refer to Energy Log Version 3 spreadsheet for documentation of daily energy inputs/outputs.

Wood Gassification (Alternate heating - Wood Gun E100)
Wood gassification is also referred to as pyrolysis. This renewable energy source was chosen over several other non-combustible options due to a preference to increase resiliency, embodied energy, and local sustainability. We looked at air-water heat pumps, water-water heat pumps, expanded solar thermal capture and storage, biogas, bio-diesel genset, and expanded solar PV for electrical heat inputs. Based on our research, with what fits with our home, gassification provided the best, most appropriate technology to meet needs into an uncertain the future. It was important for us to be able to understand the technology and to fix it locally. We spent well over a year researching the options and even had B100 (pure recycled biodiesel) tested in a diesel hot water heater)

Propane for Food prep/preservation
Our six member family with two kitchens and two propane ranges used 300 pounds of propane in a 12 month period (1901 kWhrs). As mentioned we produce and process most of the families food and therefor do not import the embodied energy or water.

Solar Thermal for cooking/ food preservation:

1. The family also diverts some of the summer heat dump from the solar thermal into a food dehydrator at the back of the house. There is a copper coil, pump, 12DC fan, and thermostat in a highly insulated earthen box.
2. The 75deg C water at the top of the hot water tank is regularly used to fill the kettle or pot thus dramatically reducing the propane requirement for boiling water.

Energy Source	Total kWhrs	kWhrs/ft2 (based on 2500ft2)	kWhrs/ft2/person
Electricity Produced	2,469	0.99	0.16
Electricity Sold	-315	-0.13	-0.02
Solar Thermal	4,238.0	1.70	0.28
Wood (3 cords Douglas Fir)	16,705	6.68	1.11
Propane	1,901	0.76	0.13
Total	**24,998.0**	**10.00**	**1.67**

See Following page (page 6) for Table of Energy Inputs

Table of Energy Inputs:

month	Wood Inputs kbtu (kWhrs)	Available Solar Thermal Inputs kbtu (kWhrs)	Actual Solar Thermal Inputs kbtu (kWhrs)	DHW in gallons used	DHW output kbtu (kWhrs)	Space Heating kbtu (kWhrs)	Solar PV Inputs
January	14250 (4176.26)	682 kbtu (199.87)	682 kbtu (199.87)	694.5	484.8 (134.6)	14447.2	
February	8550 (2505.76)	1148 kbtu (336.45)	1148 kbtu (336.45)	694.5	484.8 (134.6)	9213.2	
March	6270 (1837.55)	1612 (472.43)	1612 (472.43)	694.5	484.8 (134.6)	7397.2	
April	570 (167.05)	1920 (562.7)	1920 (562.7)	694.5	484.8 (134.6)	2005.2	
May	N/A	2294 (672.31)	2294 (672.31)	694.5	484.8 (134.6)	1809.2	
June	N/A	2220 (650.62)	484.8 (134.6)	694.5	484.8 (134.6)	n/a	
July	N/A	2604 (763.16)	484.8 (134.6)	694.5	484.8 (134.6)	n/a	
August	N/A	2400 (703.37)	484.8 (134.6)	694.5	484.8 (134.6)	n/a	
September	N/A	2280 (668.2)	2280 (668.2)	694.5	484.8 (134.6)	1795.2	
October	4560 (1336.4)	1550 (454.26)	1550 (454.26)	694.5	484.8 (134.6)	5625.2	
November	8550 (2505.76)	900 (263.76)	900 (263.76)	694.5	484.8 (134.6)	8965.2	
December	14250 (4176.26)	620 (181.7)	620 (181.7)	694.5	484.8 (134.6)	14285.2	
Totals	**57000 (16705 kWhrs)**	**20230 (5928.83 kWhrs)**	**14460.4 (4237.93 kWhrs)**	**8334**	**5817 (1615.2 kWhrs)**	**65542.8 (19,208 kWhrs)**	**7349.8 (2154 kWhrs)**

TABLE SUMMARY:

Overall annual energy use with wood + actual solar thermal inputs =71.46 MMbtu
Space Heating Intensity = 26.22 kbtu/ft2/yr (7.68 kWhrs/ft2/yr)
Overall energy intensity less propane inputs = 28.58 kbtu/ft2/yr (8.38 kWhrs/ft2/yr)
Additional Energy from 300 lbs propane - for two ranges 6486.6 kbtu or 6.4866 MMbtu

Electrical Energy consumed 2154 kWhrs or 7349.8 kbtu (7.3498 MMbtu)

Overall Energy intensity with all energy inputs is:
Wood 57000 kbtu - (16705 kWhrs)
Actualized solar 14460.4 kbtu - (4238 kWhrs)
Solar PV 7349.8 kbtu - (2154 kWhrs)
Propane 6486.6 kbtu - (1901 kWhrs)
Total energy = 85.297 MMbtu - (24,998 kWhrs)
Total Energy Intensity = 34.1 kbtu/ft2/yr (9.99 kWhrs/ft2/yr)

Notes on Solar thermal and Wood gassification:
In the months May through September the only thermal energy inputs are Solar Thermal, used almost exclusively for the heating of the domestic hot water. Obviously we have excess heat, so much of what we are capable of generating is not collected/used (due to high temperatures in the solar storage tank and corresponding low temperature differentials between collectors and the storage system). Due to this, the energy used during this period is calculated based on the premise that we use an average volume per month of domestic hot water, that that the volume that leaves the tank at 54.4C (130 F) is replaced with cold water at 7C thus creating a temperature differential of 47.4C.

Notes on Domestic Hot Water Energy Inputs:
Our water meters are in US gallons, 1 US gallon equals 3.785 litres
1 US gallons weighs 8.2 lbs or 3.719 kg
To determine energy required to heat the domestic hot water used we used the following equation:
Q = specific heat capacity of water X weight in kg X Temperature raised in degrees C
Q=4.19 kJ/kg X 1.0kg X 47.4 C
Q=198 kJ
Q is the required energy to heat 1 kg of water 47.4 C
We use 8335 US gallons of DHW/year or 694.5 gallons/month; this is the same as 30,997.9 kg/year or 2583 kg/month
Thus per year it takes 198kj/kg X 30,997.9 kg or 6,137,584.2 kj (5817 kbtu, or 1616 kWhrs) to heat the DHW used for the residence. Per month these figures are as follows; 511,465.4 kj (484.8 kbtu, or 134.6 kWhrs)

Notes on Wood inputs:
The first year living in the house we used 2.5 chords of douglas fir and scraps of recycled wood from the building of the house. We estimated that in total this equates to 3 chords of wood. It is found that D.Fir has between 18.1 and 20 Mbtu of recoverable energy per chord, thus we calculate the input as follows; 3 X 19 Mbtu = 57 Mbtu, or 16,705 kWhrs of energy inputs. Based on the number of days the gassification boiler is used we have a percentage of energy that is attributable to wood for the months of October through April. The percentage of the energy that is allocated through these

months is as follows; October - 8%, November - 15%, December - 25%, January - 25%, February - 15%, March - 11%, April - 1%.

Gord and Ann Baird